

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
13 December 2001 (13.12.2001)

PCT

(10) International Publication Number  
**WO 01/94916 A1**

- (51) International Patent Classification<sup>7</sup>: **G01N 21/35, G02B 5/20, 5/28**
- (21) International Application Number: **PCT/GB01/02377**
- (22) International Filing Date: **30 May 2001 (30.05.2001)**
- (25) Filing Language: **English**
- (26) Publication Language: **English**
- (30) Priority Data:
- |           |                                |    |
|-----------|--------------------------------|----|
| 0013409.8 | 2 June 2000 (02.06.2000)       | GB |
| 0022427.9 | 13 September 2000 (13.09.2000) | GB |
- (71) Applicant (*for all designated States except US*): **LATTICE INTELLECTUAL PROPERTY LTD. [GB/GB]; 130 Jermyn Street, London SW1Y 4UR (GB).**
- (72) Inventor; and
- (75) Inventor/Applicant (*for US only*): **HODGKINSON, Elizabeth, Jane [GB/GB]; 1 Mansfield Avenue, Quorn, Loughborough, Leicestershire LE12 8BD (GB).**
- (74) Agent: **BURRIDGE, John, R., W.; Lattice Intellectual Property Ltd., 23 Buckingham Gate, London SW1E 6LB (GB).**
- (81) Designated States (*national*): **AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW.**
- (84) Designated States (*regional*): **ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).**

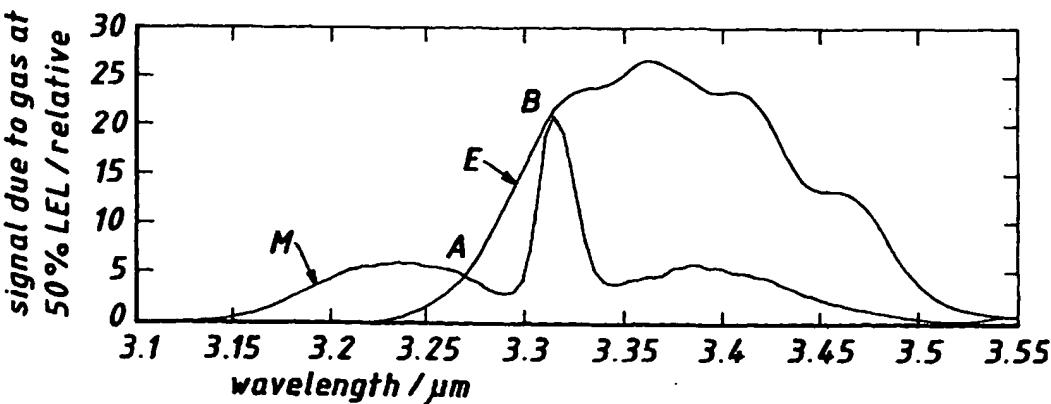
**Published:**

— *with international search report*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

---

(54) Title: **NON-DISPERSIVE IR MEASUREMENT OF GASES USING AN OPTICAL FILTER**



WO 01/94916 A1

(57) Abstract: A method and apparatus are described for determining the safety of a gas mixture containing flammable components such as methane together with ethane or other hydrocarbon, together with a diluent gas. The method comprises the filtered infrared spectroscopy of the gas mixture in a gas cell (10) using a filter (16). The peak transmission wavelength ( $\lambda_{\max}$ ) and bandwidth of the filter (16) are so chosen to provide an output, when an infrared light source (42) having a flat wavelength distribution is used, indicative of the %LEL of the gas mixture, within a predetermined tolerance. The filter may be a gas correlation filter containing a mixture of methane and ethane, together with a diluent gas.

NON-DISPERSIVE IR MEASUREMENT OF GASES USING AN OPTICAL FILTER

Field of the invention

The present invention relates to various aspects of determining the safety of a gas mixture which contains flammable components by infrared spectroscopy, especially but not exclusively where the gas mixture contains methane and ethane in unknown proportions.

Background of the invention

Flammable gas concentration measurements are made in a number of safety-critical situations. One such flammable gas is natural gas, which typically comprises mainly methane, plus higher hydrocarbons, inert gases and trace components. Natural gas detectors are needed for a number of applications including response to public reported gas escapes and for continuous monitoring of plant / equipment using permanently installed detectors. They are required to measure the gas concentration as a percentage of the lower explosion limit (LEL) of the gas mixture, this being an important safety parameter.

The concentration of a flammable gas component, such as methane, in a gas mixture can, theoretically, be measured by infrared spectroscopy, using a filter having a peak transmission wavelength equal to one of the wavelengths of absorption by methane, e.g. at  $3.32\text{ }\mu\text{m}$ . The filter and the light source together define a selected range of wavelengths over which the spectral measurement of the gas mixture is made, giving a degree of selectivity for individual gas species. The measured concentration can be converted into %LEL to give an indication of the safety of the gas mixture. However, gas mixtures from natural sources will usually contain unknown proportions of other flammable components, such as hydrocarbons including ethane, propane and butane, while in some cases such

components are deliberately added. The presence of these additional flammable components disturbs the accuracy of the %LEL measurement, by absorbing infrared radiation to a degree which is out of proportion with their influence on LEL, relative to methane.

Summary of the invention

It is an object of the present invention to provide a filter for use in the infrared spectroscopy of a gas mixture, which enables a more accurate indication of %LEL to be achieved.

We have discovered that not only the peak transmission wavelength of the filter, but also its band width are important and that improved accuracy can be achieved by suitable selection of these factors.

Thus, according to a first aspect of the invention, there is provided a method for determining the safety of a gas mixture containing first and second flammable components, together with a diluent gas, comprising the filtered infrared spectroscopy of the gas mixture using a filter, the peak transmission wavelength ( $\lambda_{max}$ ) and bandwidth of which are so chosen to provide an output indicative of the %LEL of the gas mixture, within a predetermined tolerance.

The invention is particularly advantageous where the two flammable components exhibit some absorption of infrared in the same region of the spectrum. Typical examples are components having a some chemical similarity, such as members of the same chemical series. Thus, the first flammable component will typically be methane and the second flammable component will be ethane, propane or a mixture thereof. When the first component is methane, the invention is less successful where the second component is hydrogen.

The diluent components present in the gas mixture will in practise usually be air, i.e. nitrogen, oxygen, carbon dioxide, water vapour and inert gases, but the invention is applicable to gas mixtures where the diluent components do not have a significant infrared absorption close to the peak transmission wavelength of the filter. Gas components which do have a significant infrared absorption close to the peak transmission wavelength of the filter will disturb the measurement and are therefore preferably avoided.

The filter is preferably so chosen that the output is indicative of the %LEL for the mixture, within a tolerance of  $\pm 3\%$ .

We have found that this accuracy can be achieved by the application of certain criteria to the selection of the filter.

Firstly, we have found that it is preferred that the peak transmission wavelength and the band width of the filter are so chosen that, when viewed through said filter, the intensity of transmission ( $I_1$ ) through a gas mixture containing 50% LEL of said first component is equal to the intensity of transmission ( $I_2$ ) through a gas mixture containing 50% LEL of said second component, within a tolerance of 30%, preferably within 20%, ideally within 10%. For mixtures of methane and ethane in air,

$$I_{\text{methane}} \approx I_{\text{ethane}}$$

occurs, depending upon the band width, at wavelengths of about  $3.27 \mu\text{m}$  and about  $3.32 \mu\text{m}$  in the mid infrared region, and at wavelengths of about  $1.67 \mu\text{m}$  in the near infrared region.

A second preferred criterion is that, at the peak transmission wavelength of the filter, the rate of change of intensity with increasing wavelength ( $\delta I_1/\delta\lambda$ ) for the gas mixture containing 50% LEL of said first component is equal to the rate of change of intensity with increasing wavelength ( $\delta I_2/\delta\lambda$ ) for the gas mixture containing 50% LEL of said second component, within a tolerance of 100  $I/\mu\text{m}$ , preferably within 10  $I/\mu\text{m}$ . For mixtures of methane and ethane in air we have found that

$$\delta I_{\text{methane}}/\delta\lambda \approx \delta I_{\text{ethane}}/\delta\lambda$$

and that

$$I_{\text{methane}} \approx I_{\text{ethane}}$$

occurs at a wavelength of about  $3.32 \mu\text{m}$  and a band width, expressed in terms of full width at half maximum, of less than  $0.7\% \lambda_{\text{max}}$ .

Thus, in the mid infrared region we prefer that the filter has a peak transmission wavelength  $\lambda_{\text{max}}$  of (i) from  $3.263$  to  $3.271 \mu\text{m}$ , most preferably from  $3.265$  to  $3.269 \mu\text{m}$ , with a bandwidth of between 0.8% and 1%, or (ii) between  $3.31$  and  $3.32 \mu\text{m}$ , with a bandwidth of less than 0.7%. In the near infrared region we prefer that the filter has a peak transmission wavelength  $\lambda_{\text{max}}$  of from  $1.67$  to  $1.68 \mu\text{m}$ , most preferably from  $1.673$  to  $1.675 \mu\text{m}$ , with a bandwidth of between 0.5% and 6%.

A filter having  $\lambda_{\text{max}} = 3.27 \mu\text{m}$  and a band width of  $0.9\% \lambda_{\text{max}}$  is commercially available from NDC Infrared Engineering of Galliford Road, Malden, Essex, UK. The same manufacturers can also provide a filter having  $\lambda_{\text{max}} = 1.67 \mu\text{m}$  and a band width of  $0.9\% \lambda_{\text{max}}$ . More preferred filters can be manufactured with suitable adjustments to known processing techniques, or by selection from a variety of filters, to provide a product with the desired characteristics.

It is indeed surprising that, in the mid infrared region, reducing the band width of the filter improves the accuracy of the % LEL measurement, since reducing the band width significantly reduces signal strength. It is also surprising that moving  $\lambda_{\max}$  to a position where  $I_{\text{methane}}$  and  $I_{\text{ethane}}$  are substantially equal, at a band width of less than 0.7%  $\lambda_{\max}$ , improves the accuracy of the %LEL measurement.

The invention provides the advantage that the preferred filter characteristics are independent of relative proportions of gases in the gas mixture to be examined.

According to a second aspect, the invention provides an apparatus for determining the safety of a gas mixture containing first and second flammable components, together with a diluent gas, the apparatus comprising a region for receiving gas to be examined, an infrared light source positioned to direct infrared light through said region, a sensor for measuring the intensity of light passed through said region and a filter, positioned in the light path between the source and the sensor, characterised in that the peak transmission wavelength ( $\lambda_{\max}$ ) and bandwidth of the filter are so chosen to provide the sensor with an output indicative of the %LEL of the gas mixture, within the predetermined tolerance.

The region for receiving gas to be examined may be provided by a gas cell for containing a sample of such gas, or be provided by an open optical path through which gas to be examined can flow.

The invention also provides a filter for use in the infrared spectroscopy of a gas mixture containing methane as a first component and a second component selected from ethane, propane and mixtures thereof, together with a diluent gas, characterised in that the peak transmission wavelength ( $\lambda_{\max}$ ) and bandwidth of the filter is such as to provide an output, when an infrared light source having a

flat wavelength distribution is used, indicative of the %LEL of the gas mixture, within a predetermined tolerance.

The nature of the infrared light source is a secondary consideration. In theory, if the light source has a "white" output, that is a flat wavelength distribution in that part of the spectrum being examined, then it has no effect upon the preferred characteristics of the filter. However, in practice, the infrared light source may not have a flat distribution, particularly if an LED is used as the light source. In this event, it is preferred to select the filter characteristics with the characteristics of the infrared light source in mind. Similar considerations also apply to the sensor.

Thus, also provided by the invention is the combination of an infrared light source and a filter for use in the infrared spectroscopy of a gas mixture containing methane as a first component and a second component selected from ethane, propane and mixtures thereof, together with a diluent gas, characterised in that the peak transmission wavelength ( $\lambda_{max}$ ) and bandwidth of the filter is such as to provide an output, when the light source is used, indicative of the %LEL of the gas mixture, within the predetermined tolerance.

While interference filters are suitable for use in the invention, a gas correlation filter may alternatively be used.

Thus, in an alternative embodiment, the filter comprises a gas correlation filter containing a known mixture of the first and second flammable components, together with a diluent gas.

The invention still further provides a gas correlation filter for use in the infrared spectroscopy of a natural gas, the filter containing a mixture of methane and a second flammable component selected from ethane, propane and mixtures thereof, together with a diluent gas.

The invention will now be illustrated, purely by way of example, by reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of an apparatus for determining the safety of a gas mixture;

Figure 2 is a simulation graph showing the output signal at 50%LEL for methane and ethane using a mid infrared filter with a band width of 0.9% $\lambda_{max}$ ;

Figure 3 is a simulation graph showing the output signal at 50%LEL for methane and ethane using a mid infrared filter with a band width of 0.6% $\lambda_{max}$ ; and

Figures 4a and 4b show actual experimental results obtained using an interference filter with peak transmission at  $3.266\mu\text{m}$  and an interference filter with peak transmission at  $3.324\mu\text{m}$ , respectively, to measure the concentration of various gas mixtures on the %LEL scale.

Referring to Figure 1, there is shown an apparatus for determining the safety of a gas mixture containing first and second flammable components, together with a diluent gas. The apparatus comprises a region for receiving gas to be examined provided by a gas cell 10 for containing such a sample of gas. An infrared light source 12 is positioned to direct infrared light through the gas sample in the cell 10. A suitable infrared light source is Chemled LED 33, ex Telecom Devices

Corporation, available through Access Pacific Ltd, Wellingborough, Northants, UK. A sensor 14 is provided for measuring the intensity of light passed through the gas sample in the cell. A suitable sensor is P791-11 PbSe photodetector ex Hamamatsu Photonics UK Ltd, Enfield, UK. A filter 16 is positioned between the IR light source 12 and the cell 10, but may in an alternative configuration be positioned between the cell 10 and the sensor 14. Lenses 18 and 20 are provided to ensure that the light from the source 12 is focussed onto the sensor 14. Selection of a near infrared light source and detector, together with the near infrared filters described above, would also result in an acceptable apparatus.

Referring to Figure 2, it can be seen that between the wavelengths of  $3.1 \mu\text{m}$  and  $3.55 \mu\text{m}$ , the absorption spectra of methane (line M) and ethane (line E) are very different. However, they are found to cross at point A, at a wavelength of about  $3.267 \mu\text{m}$ . This Figure indicates preferred characteristics for the filter, namely a peak transmission wavelength of about  $3.267 \mu\text{m}$ . However, at this wavelength, the slope of each line is not similar, i.e. the rate of change of intensity with increasing wavelength for the two gases is different. This does not therefore indicate the most preferred characteristics for the filter, for which reference should be made to Figure 3. However, close examination of the slopes of the lines at point A, will indicate that a band width of  $0.9\% \lambda_{\max}$  or less will lead to an error in the measurement of %LEL for a 90/10 methane / ethane mixture of no more than 3%.

Referring to Figure 3, where the band width of the filter is reduced to 0.6%, it can be seen that there is now a second region B in which the lines M and E are close to each other. This is at a wavelength of about  $3.32 \mu\text{m}$ . Furthermore, at this wavelength, the slope of each line is similar, i.e. the rate of change of intensity with increasing wavelength for the two gases is substantially equal. This Figure

indicates the most preferred characteristics for the filter, namely a peak transmission wavelength of about  $3.315 \mu\text{m}$  and a band width of about  $0.6\%\lambda_{\max}$ .

It can also be seen from Figure 3, that the overall signal strength is reduced, compared to Figure 2.

#### Experimental example

Experiments will now be described that confirm the practical application of the previous simulation analysis. By way of example, experiments were conducted using the mid infrared filters described above, but the principle is equally applicable to near infrared operation.

A laboratory FTIR spectrometer (Biorad FTS-60A) was used to demonstrate the benefit of choosing filters referred to above. The concentration of a series of test gas mixtures was established using two interference filters, the mixtures being indicative of natural gas compositions found in the UK. The test gas mixtures had the compositions given in Table 1.

<u>Gas component</u>	<u>Composition 1</u>	<u>Composition 2</u>	<u>Composition 3</u>
Nitrogen	1.72	0.731	2.21
Carbon dioxide	0.32	2.11	0.8
Methane	93.55	86.48	92.86
ethane	3.27	7.47	3.02
propane	0.763	2.5	0.635
i-butane	0.122	0.182	0.131
n-butane	0.153	0.392	0.156
n-pentane	0.103	0.13	0.18
C6+	0	0.0003	0.0002
LEL / %vol	4.89 %vol	4.63 %vol	4.94 %vol

Table 1. Compositions in mol% of three artificial gas mixtures typical of natural gas. LELs have been calculated according to the method given by Coward and Jones using LELs of individual components from BS EN 50054:1991.  
(Reference: HF Coward and GW Jones. Limits of flammability of gases and vapours. National Bureau of Mines, Bulletin 503 [1952])

The natural gases at 100% were blended with hydrocarbon free air in varying proportions. The concentration was determined using a methane analyser (ADC dual Luft cell), which was separately adjusted for the cross-sensitivity to the other components of each gas mixture to give an accurate reading for each.

Gas spectra were measured using a 10cm pathlength gas cell in a laboratory FTIR spectrometer. Spectra were measured in the mid infrared (centred around  $3.3\mu\text{m}$ ). The spectrometer (Bio-Rad FTS-60A) was set up according to the manufacturer's instructions, for high resolution mid infrared spectroscopy. A high temperature ceramic light source was used, with a wide band KBr beamsplitter and liquid nitrogen cooled MCT detector, all of these being supplied with the spectrometer.

KBr windows were also used in the gas cell. The highest available resolution ( $0.25\text{ cm}^{-1}$ ) was chosen.

Spectra from the sample gases were corrected for cell absorptions and reflections by subtraction of a reference spectrum, taken with the cell filled with hydrocarbon free air. For each spectrum, a baseline zero was established by interpolation of a straight line between the average absorption in the following two regions: (i)  $3.0\text{-}3.1\mu\text{m}$ , and (ii)  $3.9\text{-}4\mu\text{m}$ . These regions were chosen for their insignificant levels of absorption for natural gas. Baseline zero reference measurements, made using carefully selected filters in regions unaffected by gas absorption, are well-known in non-dispersive infrared gas detectors.

The measurement performance of two different interference filters was compared. The first was chosen according to the previous text, to have a transmission peak close to  $3.267\mu\text{m}$  (actually  $3.266\mu\text{m}$ ) and a fwhm bandwidth of under 0.9% (actually 0.81%). The second was chosen so as to maximise the signal from methane, with a transmission peak at  $3.324\mu\text{m}$  that corresponded with the maximum available methane signal, and a fwhm bandwidth of 0.83%.

(All figures provided by the manufacturer, NDC Infrared Engineering, Maldon, Essex, UK.)

The transmission spectra of each of the two interference filters was measured separately using the FTIR spectrometer with the same configuration settings as before. The effect of using each filter to make a non-dispersive measurement of gas concentration was then evaluated as follows.

Working in the transmission domain, the transmission spectrum of one of the filters was multiplied by the transmission spectrum of one of the gas mixtures.

This gave a signal equivalent to the transmission spectrum when the filter and gas cell were placed in series in the optical path of the spectrometer. The total amount of light that would pass through the cell / filter in this circumstance was calculated by integrating the light transmission in a broad window from 3.0 to 3.7  $\mu\text{m}$ . This gave a signal equivalent to that measured by a single non-dispersive gas detector whose spectral selection of the gas absorption was determined by the interference filter alone.

This analysis was repeated for every combination of each of the two filters and three gas mixtures, plus a methane control, over a range of concentrations covering the %LEL scale.

The synthesised signals, in arbitrary units, were larger when using the second interference filter than when using a first interference filter. A single calibration factor was therefore applied to all the data obtained using each interference filter. This factor was chosen so as to give accurate results for the methane control gas at high concentrations.

#### Experimental results

At a range of gas concentrations, the signals obtained for the different gas mixtures as set out in Table 1 when using each of the two interference filters are shown in Figures 4a and 4b.

A degree of nonlinearity can be observed in the results in Figures 4a and 4b, as a consequence of saturation effects associated with Beer's Law at high absorption levels. The degree of nonlinearity is greater in Figure 4b, which is consistent with the second interference filter selecting a range of absorption lines with greater

levels of absorption. Such nonlinearities can be reduced by using a calibration look-up table or by using a shorter optical pathlength through the gas cell.

It is clear from Figures 4a and 4b that use of the first interference filter at  $3.266\mu\text{m}$  (Figure 4a) has resulted in a small spread of results for different gas mixtures at the same concentration. In contrast, the spread of results found when using the second interference filter (Figure 4b) is much greater. When using gas detectors to quantify natural gas leaks, the composition of natural gas, to a degree represented by the above data, is not known. If calibrated using a methane only reference, a gas detector based on the second filter could overestimate the level of natural gas in real gas leaks by up to 100% because of inappropriate cross-sensitivity to the non-methane components of the natural gas.

The range of proportional errors associated with each filter was calculated for each gas concentration used. The average error range for the first interference filter was 10%, while that for the second filter was 36%. Even if methane is excluded from the analysis, the mean error range with the first filter is 5% compared to 19% with the second. It is clear that an appropriately chosen filter can significantly reduce the level of composition-related error for gas detectors based on non-dispersive infrared measurements.

## CLAIMS

1. A method for determining the safety of a gas mixture containing first and second flammable components, together with a diluent gas, comprising the filtered infrared spectroscopy of the gas mixture using a filter, the peak transmission wavelength ( $\lambda_{\max}$ ) and bandwidth of which are so chosen to provide an output indicative of the %LEL of the gas mixture, within a predetermined tolerance.
2. A method according to claim 1, wherein said first flammable component is methane.
3. A method according to claim 2, wherein said second flammable component is selected from ethane, propane and mixtures thereof.
4. A method according to any preceding claim, wherein said output is indicative of the %LEL for the mixture, within a tolerance of  $\pm 3\%$ .
5. An apparatus for determining the safety of a gas mixture containing first and second flammable components, together with a diluent gas, the apparatus comprising a region for receiving gas to be examined, an infrared light source positioned to direct infrared light through said region, a sensor for measuring the intensity of light passed through said region and a filter, positioned in the light path between said source and said sensor, characterised in that the peak transmission wavelength ( $\lambda_{\max}$ ) and bandwidth of said filter are so chosen to provide said sensor with an output indicative of the %LEL of the gas mixture, within a predetermined tolerance.

6. An apparatus according to claim 5, in which the gas region is provided by a gas cell for containing a sample of gas to be examined.
7. An apparatus according to claim 5, in which the region is provided by an open optical path through which gas to be examined can flow.
8. An apparatus according to claim 5, 6 or 7, wherein the peak transmission wavelength and the band width of the filter are so chosen that, when viewed through said filter, the intensity of transmission through a gas mixture containing 50%LEL of said first component is equal to the intensity of transmission through a gas mixture containing 50%LEL of said second component, within a tolerance of 30%.
9. An apparatus according to any of claims 5 to 8, wherein said filter comprises a gas correlation filter containing a known mixture of said first and second flammable components, together with a diluent gas, to provide said sensor with an output indicative of the %LEL of the gas mixture, within a predetermined tolerance.
10. A method according to claim 9, wherein, at the peak transmission wavelength of the filter, the rate of change of intensity with increasing wavelength for the gas mixture containing 50% LEL of said first component is equal to the rate of change of intensity with increasing wavelength for the gas mixture containing 50% LEL of said second component, within a tolerance of 100 times the signal level per  $\mu\text{m}$ .
11. A filter for use in the infrared spectroscopy of a gas mixture containing methane as a first component and a second component selected from

ethane, propane and mixtures thereof, together with a diluent gas, characterised in that the peak transmission wavelength ( $\lambda_{\max}$ ) and bandwidth of the filter is such as to provide an output, when an infrared light source having a flat wavelength distribution is used, indicative of the %LEL of the gas mixture, within a predetermined tolerance.

12. A filter according to claim 11, wherein said filter has a peak transmission wavelength  $\lambda_{\max}$  of from 3.265 to 3.269  $\mu\text{m}$ .
13. A filter according to claim 12, wherein said filter has a band width, expressed in terms of full width at half maximum, of less than 0.9% $\lambda_{\max}$ .
14. A filter according to claim 11, wherein said filter has a peak transmission wavelength  $\lambda_{\max}$  of from 3.31 to 3.32  $\mu\text{m}$ .
15. A filter according to claim 14, wherein said filter has a band width, expressed in terms of full width at half maximum, of less than 0.7% $\lambda_{\max}$ .
16. A filter according to claim 11, wherein said filter has a peak transmission wavelength  $\lambda_{\max}$  of from 1.673 to 1.675  $\mu\text{m}$ .
17. A filter according to claim 16, wherein said filter has a band width, expressed in terms of full width at half maximum, of between 0.5% and 6% $\lambda_{\max}$ .
18. The combination of an infrared light source and a filter for use in the infrared spectroscopy of a gas mixture containing methane as a first component and a second component selected from ethane, propane and mixtures thereof, together with a diluent gas, characterised in that the peak transmission wavelength

( $\lambda_{\text{max}}$ ) and bandwidth of the filter is such as to provide an output, when said light source is used, indicative of the %LEL of the gas mixture, within a predetermined tolerance.

19. A gas correlation filter for use in the infrared spectroscopy of a natural gas, said filter containing a mixture of methane and a second flammable component selected from ethane, propane and mixtures thereof, together with a diluent gas, in quantities that give equal signals from a mixture of methane / air at 50%LEL and from a mixture of the second flammable component and air at 50%LEL, within a tolerance of 10%.
20. A method for determining the safety of a gas mixture substantially as herein described.
21. An apparatus for determining the safety of a gas mixture substantially as herein described.
22. A filter for use in the infrared spectroscopy of a gas mixture containing methane as a first component and a second component selected from ethane, propane and mixtures thereof, substantially as herein described.
23. A gas correlation filter for use in the infrared spectroscopy of a gas mixture containing methane as a first component and a second component selected from ethane, propane and mixtures thereof, substantially as herein described.
24. The combination of an infrared light source and a filter for use in the infrared spectroscopy of a gas mixture containing methane as a first component

and a second component selected from ethane, propane and mixtures thereof, substantially as herein described.

1/4

FIG. 1.

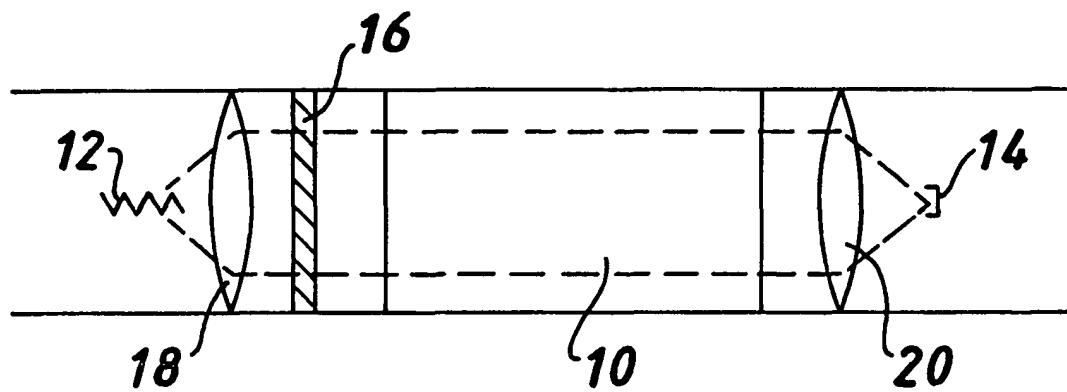


FIG. 2.

2/4

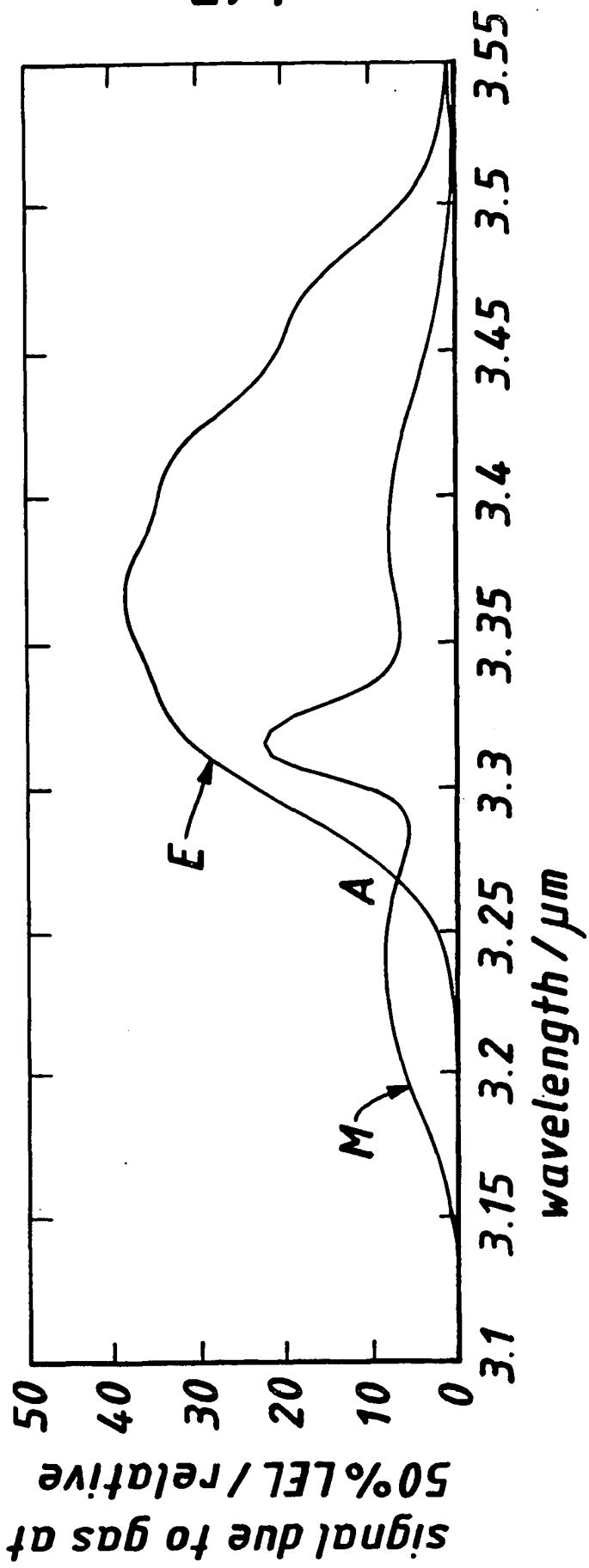
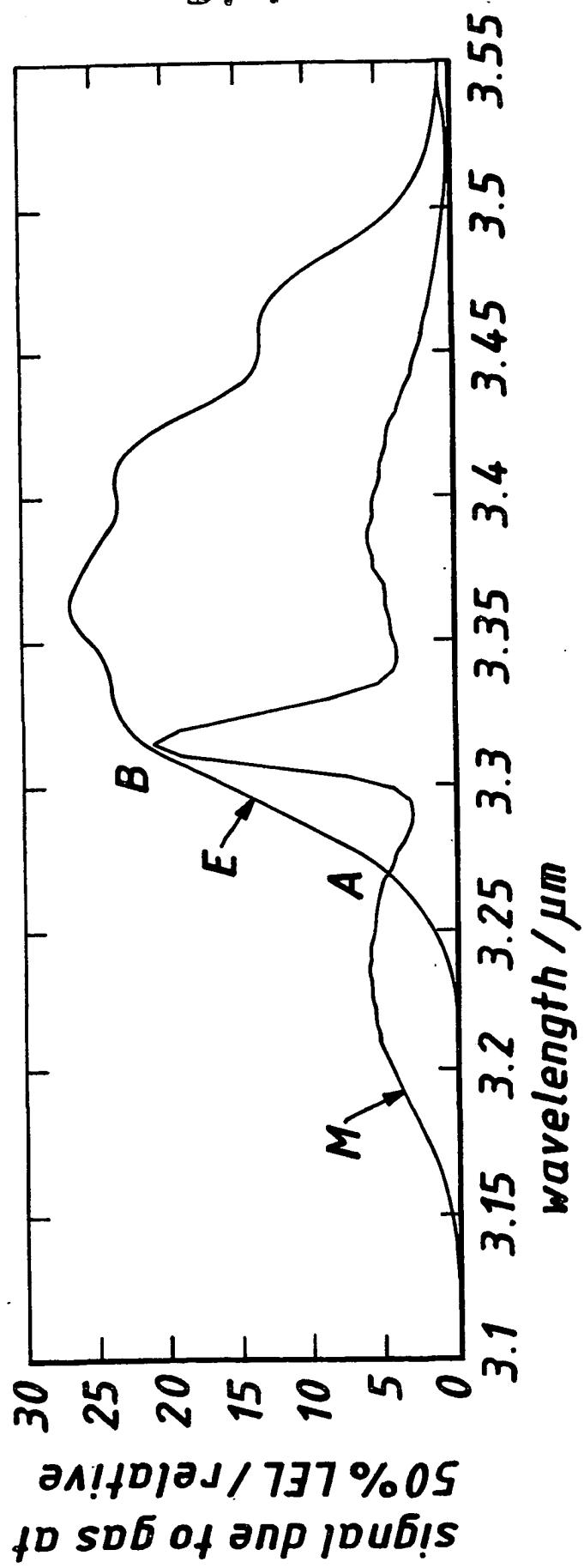
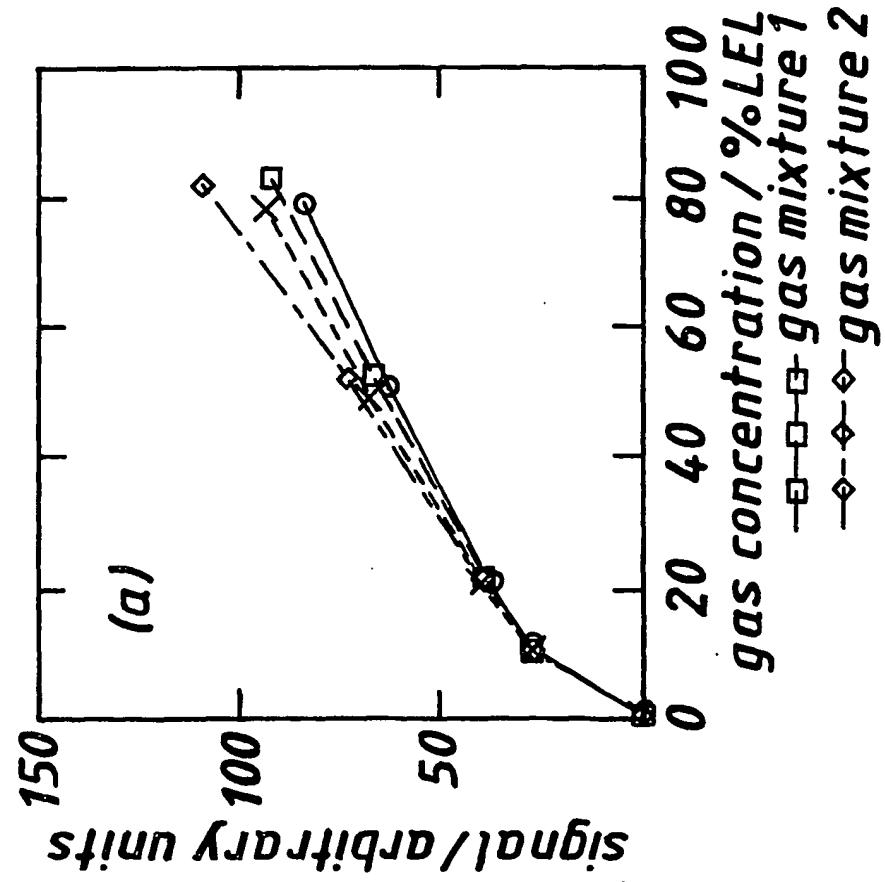


FIG. 3.

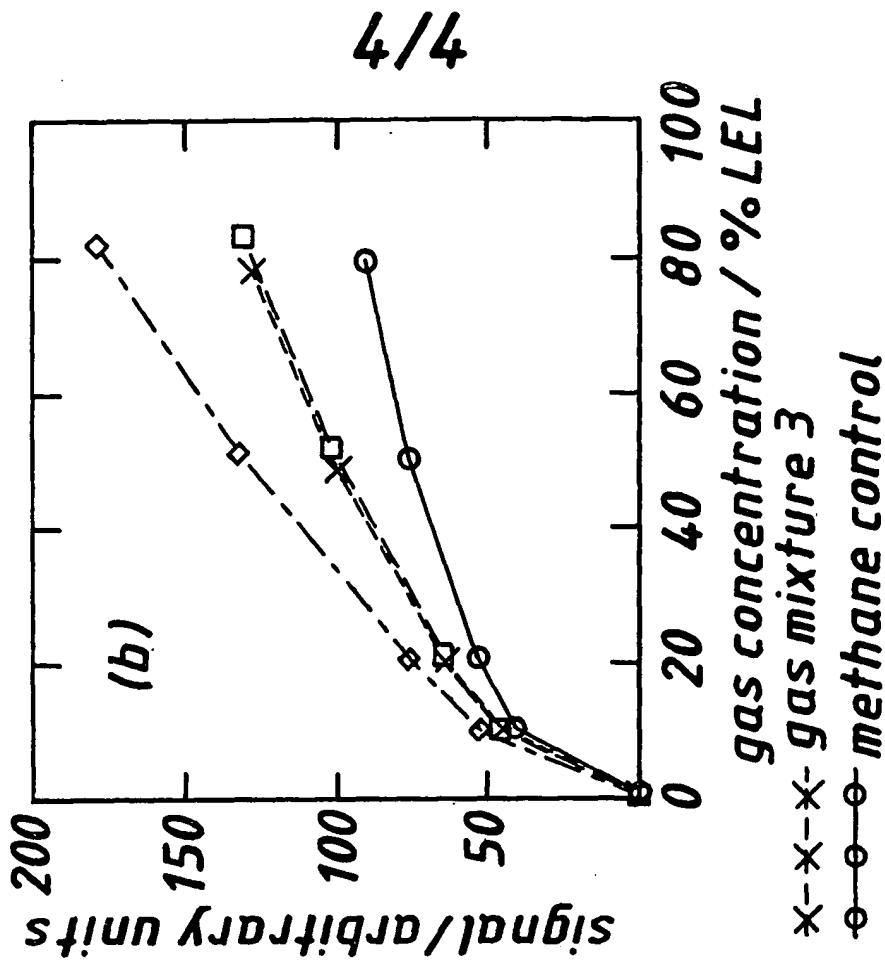
3/4



*FIG. 4a.*



*FIG. 4b.*



A. CLASSIFICATION OF SUBJECT MATTER  
 IPC 7 G01N21/35 G02B5/20 G02B5/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
 IPC 7 G01N G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 930 496 A (SPECTRONIX LTD) 21 July 1999 (1999-07-21) column 6, line 54 -column 12, line 42; figures 1,2,6 —	1-3,5-7, 11,18
X	WO 99 19712 A (ZELLWEGER ANALYTICS LTD ;RICHMAN LEE (GB)) 22 April 1999 (1999-04-22) page 1, line 27 -page 2, line 1 page 4, line 23 -page 5, line 14 page 5, line 17 -page 7, line 20 page 8, line 18 -page 9, line 3 page 11, line 24-26 page 12, line 16-26; figure 6 —	1-3,5,7, 11,18

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

° Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority, claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*&\* document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the International search report
30 July 2001	17/08/2001
Name and mailing address of the ISA  European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel: (+31-70) 340-2040, Tx. 31 651 epo nl. Fax: (+31-70) 340-3016	Authorized officer  Meyer, F

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 616 207 A (ITVI INTTECH VENTURE INVESTA) 21 September 1994 (1994-09-21) page 1, line 1-5 page 1, line 49-56 page 3, line 46-48 page 4, line 38-45; figures 1,8 -----	1-3,5,6, 11,14,18
X	US 6 037 592 A (MATTIS JOHN SEYMOUR ET AL) 14 March 2000 (2000-03-14) column 2, line 64 -column 3, line 18 column 5, line 8-15 column 8, line 33-57 column 11, line 31-50; figure 2 -----	5,6,11, 14,18
A	GB 2 176 889 A (GRAVINGER LTD) 7 January 1987 (1987-01-07) page 3, column 94-100 -----	19

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Claims Nos.: 20-24

Due to the vague and indefinite formulation "... substantially as herein described", the scope for which protection is sought is not defined in claims 20-24. Furthermore, such a reference to the description does not meet the requirements of Rule 6.2(a) PCT. Consequently, a meaningful search could not be carried out (Article 17(2)(a)(ii) PCT) for claims 20-24.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP 0930496 A	21-07-1999	US NO	6061141 A 990047 A	09-05-2000 21-07-1999
WO 9919712 A	22-04-1999	EP	1019702 A	19-07-2000
EP 0616207 A	21-09-1994	DE DE	4301457 A 4306240 A	04-08-1994 13-10-1994
US 6037592 A	14-03-2000	WO	9836265 A	20-08-1998
GB 2176889 A	07-01-1987	NO	862428 A	22-12-1986